

FINAL REPORT

INVESTIGATION OF PERSONNEL HAZARD ASSOCIATED WITH RADIO-FREQUENCY FIELDS ENCOUNTERED IN NAVAL OPERATIONS

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FOREWORD

This study consisted of research seeking to test the validity of the so-called permissible level of exposure to microwave radiation by means of biological assay techniques. Two different experimental methods, described in terms of biological and human models, were related to each other and the state-of-the-art for conducting investigations into the bio-effects of microwave irradiation was advanced. Although this specific effort was terminated prematurely, nevertheless the sponsor was provided with a substantively developed methodology to ensure that the research objectives could be achieved and an intact facility for its continuance.

The Zaret Foundation acknowledges the support of the Electrophysics Department, Graduate Center, Polytechnic Institute of Brooklyn for its collaboration in conducting the experiments described under biological models and for providing theoretical evaluations regarding the composition of the free-field emanating from the SPS-10 Radar set and transmission measurements of microwave irradiation through various cages, both wire and plastic types, utilized during portions of the free-field irradiations.

NOT REPRODUCIBLE

BACKGROUND

Pathological effects induced by exposure to non-ionizing electromagnetic radiation are often severe and irreversible. Consequently, there is concern for the safety of personnel engaged in the development, fabrication, testing and use of radiation devices. With regard to injury by microwaves, the human lens is particularly vulnerable and serves as the site for a characteristic finding, capsular opacification, as a consequence of over-exposure. Moreover, in man, usually following repeated exposures, this type of cataract appears after a long latent period. Of all the possible human indicators of past exposure to microwaves, capsular cataract appears to be the best cumulative tissue dosimeter and it records the consequence of repeated thermal insults. Therefore, it represents the criterion response for the chronic free-field exposures of the primates, serving as the HUMAN MODEL.

For the BIOLOGICAL MODEL, it was natural to utilize lower-order animals where a variety of options were available, e.g., titration dosages required (1) to interfere with the homing ability of pigeons, (2) to produce death of rats in a fixed period of time, or (3) to produce thresholds of thermal effect in rabbits. The latter was selected for the following reasons:

(1) We had just replicated (in the context of microwave bio-experimentation) a Soviet study by Presman and Levitina utilizing rabbits and demonstrated the reported findings to be in serious error in two respects, namely that effects they alluded to as nervous system effects were in fact non-existent and that 10mW/sq cm was not athermal.

(2) In improving on the Soviet methodology, we advanced the state-of-the-art by adding thermal stress indicators, temperature and respiration rate, to their measurable heart rate as determined by EKG.

(3) The threshold effect was found to be thermal stress and this serves as the criterion response for the biological model.

(4) As the relative biological effectiveness of the radiation is related to its absorption, the rabbit instrumented to indicate thermal response becomes a better physiological radiometer than any available combination of physical measurement instruments.

(5) This criterion response can be utilized in any r-f field no matter how complicated its pattern, irrespective of wave-length or whether the field is simple or complex, single or multiple frequency, pulsed or continuous waves, normal or tangential, etcetera.

A major defect regarding most previously performed biological research extrapolated to humans has been related to utilization of massive exposures and searching for immediate effects in the form of an acute injury. However, the major problem in considering personnel protection is not directly related to acute injury. Instead, the injury appearing late following chronic exposure is the principal finding relatable to health-safety. In this context, the biological

model provides a method for determining physiological thermal response thresholds while the human model provides a cumulative biological dosimeter for determining injury thresholds sustained following repeated exposure.

THE BIOLOGICAL MODEL.

The purpose of this portion of the study was to observe the biological effects of microwaves under conditions that permitted precise control of dosage levels and accurate measurement of physiological indicators. In furtherance of this objective, four experiments were conducted at the Microwave Power Laboratory of Brooklyn Polytechnic Institute in Farmingdale, New York. Experiment I observed the effects of CW microwave irradiation of the dorsal head; Experiment II, the effects of CW irradiation of the whole dorsal surface; Experiment III, the effects of infrared radiation; Experiment IV compared the effects of CW and pulsed microwaves. The results of this study indicate that a suitably instrumented rabbit can be used as a biological dosimeter to monitor microwave environments to which humans may be exposed.

Experiment I

CW Microwave Irradiation of the Head

Subjects.

The subjects were two male albino rabbits weighing 3.5 kg.

Apparatus

Microwave power was obtained from a CW magnetron with an operating frequency of 2.409 GHz ($\lambda = 12.5$ cm). Power from the tube was conducted through waveguide and cable to an irradiating horn placed in an anechoic chamber with its main lobe directed downward, so that the animal was irradiated from above. The horn aperture was $7\frac{31}{32}$ in by $5\frac{7}{8}$ in, and the animal's head was 29 in below the aperture. This distance was in the far field region, which began at $2d = 26$ in from the horn.

The power density at the location of the animal's head was measured with a Ramcor 1250A densiometer with a calibrated low-gain rectangular horn antenna. The calibration procedure was performed with the animal not present in the anechoic chamber. A coaxial thermistor mount, power meter, and directional coupler were used to monitor the power during irradiation.

The anechoic chamber had interior dimensions of 40x40x64 in and was lined with type CV-4 microwave absorber panels manufactured by Emerson-Cuming. This material is rated to have reflections better than 20 dB below the incident power level at 2.0 GHz; at 2.4 GHz the reflection is even lower. A plate of this material was used to shield the animal's back during irradiation of its head.

Procedure

The rabbit was restrained in a wooden box open at the top, except for five wooden dowels above the rabbit's back to keep him from escaping. Needle

electrodes were inserted for EKG recording; a mercury strain gauge, manufactured by Parks Electronics, was tied around the animal's thorax to sense respiration; and a Yellow Springs 524 thermistor probe was inserted subcutaneously near the midline of the lower back to measure temperature. Then the box containing the rabbit was placed below the horn antenna in the anechoic chamber for a 15 min acclimatization period. Next, EKG, respiration, and temperature were recorded once each minute for 10 min before the onset of radiation and then for 60 min during irradiation. Each EKG and respiration trace was 10 sec in duration. Each animal was exposed twice to power densities of 0, 20, 40, 60, and 80 mW/sq cm.

Results

All three physiological indicators showed the effects of microwave irradiation at 20 mW/sq cm and above. Figure 1 shows the effect on heart rate. The results for each power level are displaced vertically for the sake of legibility. At 0 mW/sq cm, the heart rate decreased while the animal was confined in the apparatus. At 20 mW/sq cm, the heart rate was steady. At 40/60/80 mW/sq cm, there was a progressively larger increase in heart rate during irradiation. The points in Fig. 1 represent the data from both animals averaged over 10-min blocks. The straight lines were fitted by a computer using the method of least squares. Wherever possible in this report, the data are fitted with straight lines. Where the functions are clearly nonlinear, quadratic or cubic equations have been fitted to the data by least squares.

Figure 2 shows the effect on respiration rate. The data points were fitted with quadratic equations because of their curvature, especially at the highest power levels. Respiration rate decreased when the animal was not irradiated, but increased at 20 mW/sq cm. The rate of increase grew progressively larger with an increase in the power level.

Subcutaneous temperature also increased during irradiation as shown by the graphs in Fig. 3, which have been displaced vertically to avoid overlap. Again the slope increased with the power level. The changes per minute of irradiation for all three indicators are summarized in Table 1. The fact that the increases in heart rate and respiration rate were accompanied by a rise in temperature indicates that the rate changes are thermal effects. Remember that the thermistor was placed in an area shielded from irradiation, so that it measured a generalized increase in body temperature.

The next experiment shows that the radiation effects are even larger when the head and back are both exposed.

Experiment II

CW Microwave Irradiation of the Whole Dorsal Surface

Subjects

Two male albino rabbits weighing 3.5 kg.

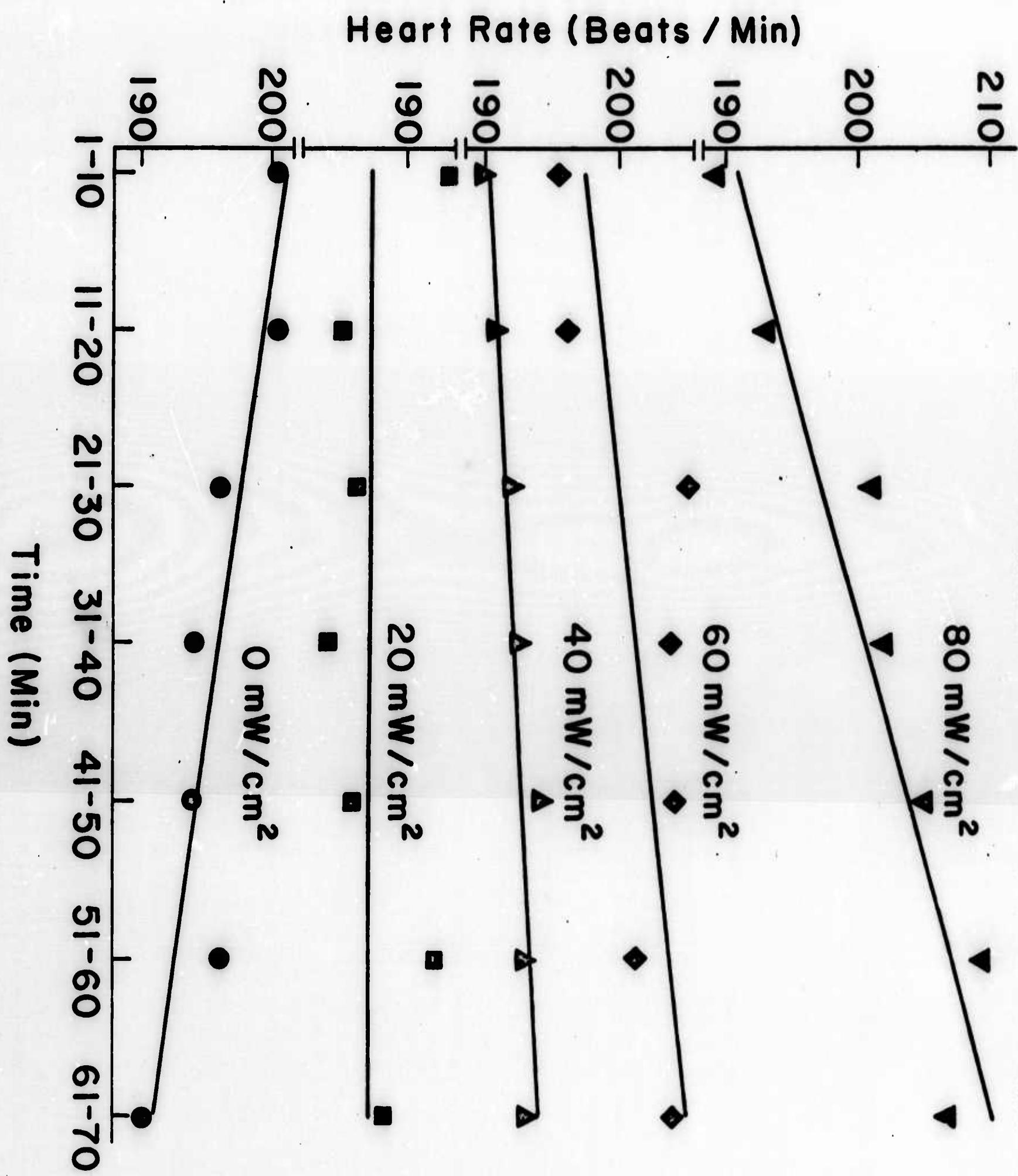


Fig. 1 Effect on heart rate of CW microwave irradiation of the head

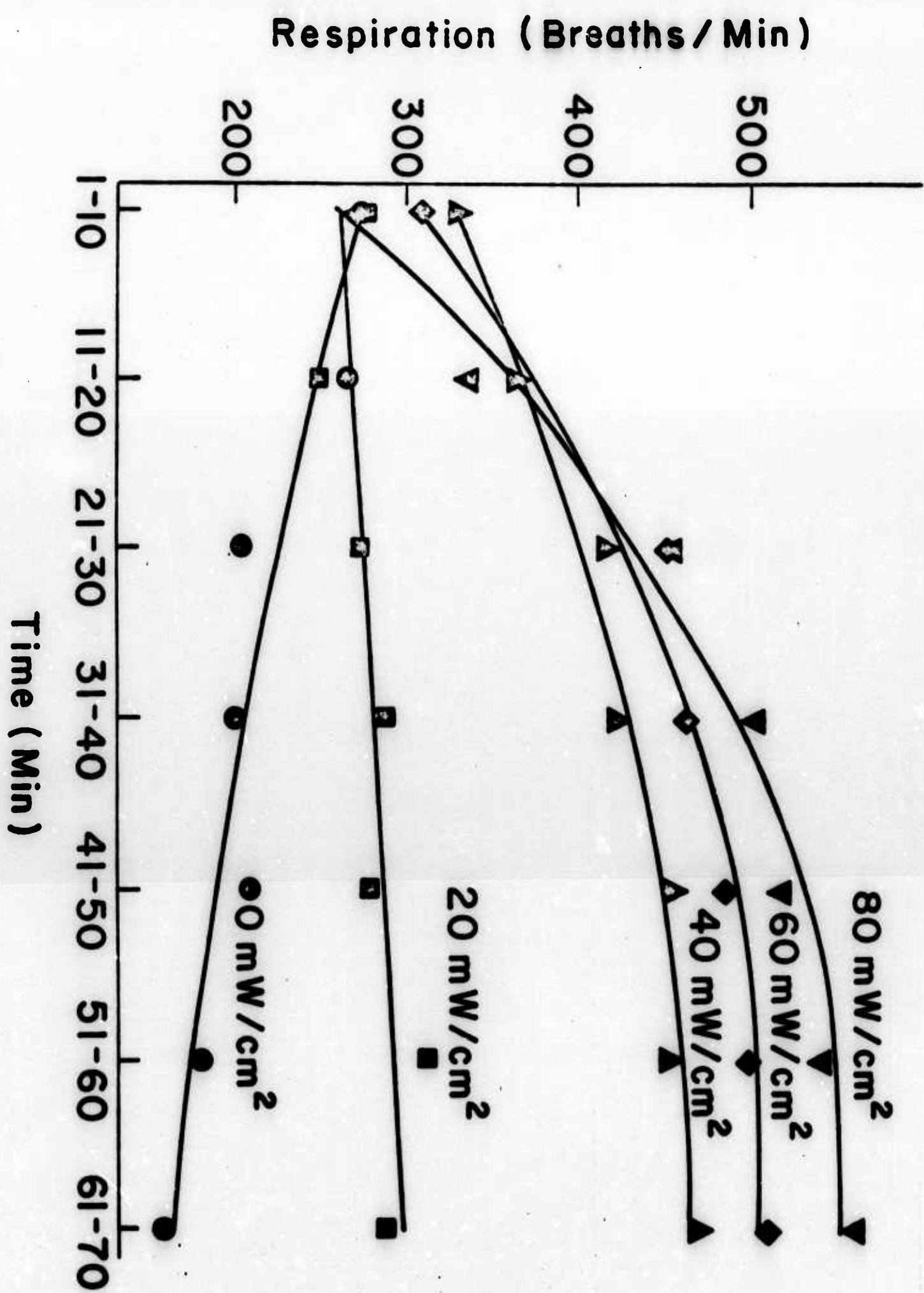


Fig. 2 Effect on respiration rate of CW microwave irradiation of the head

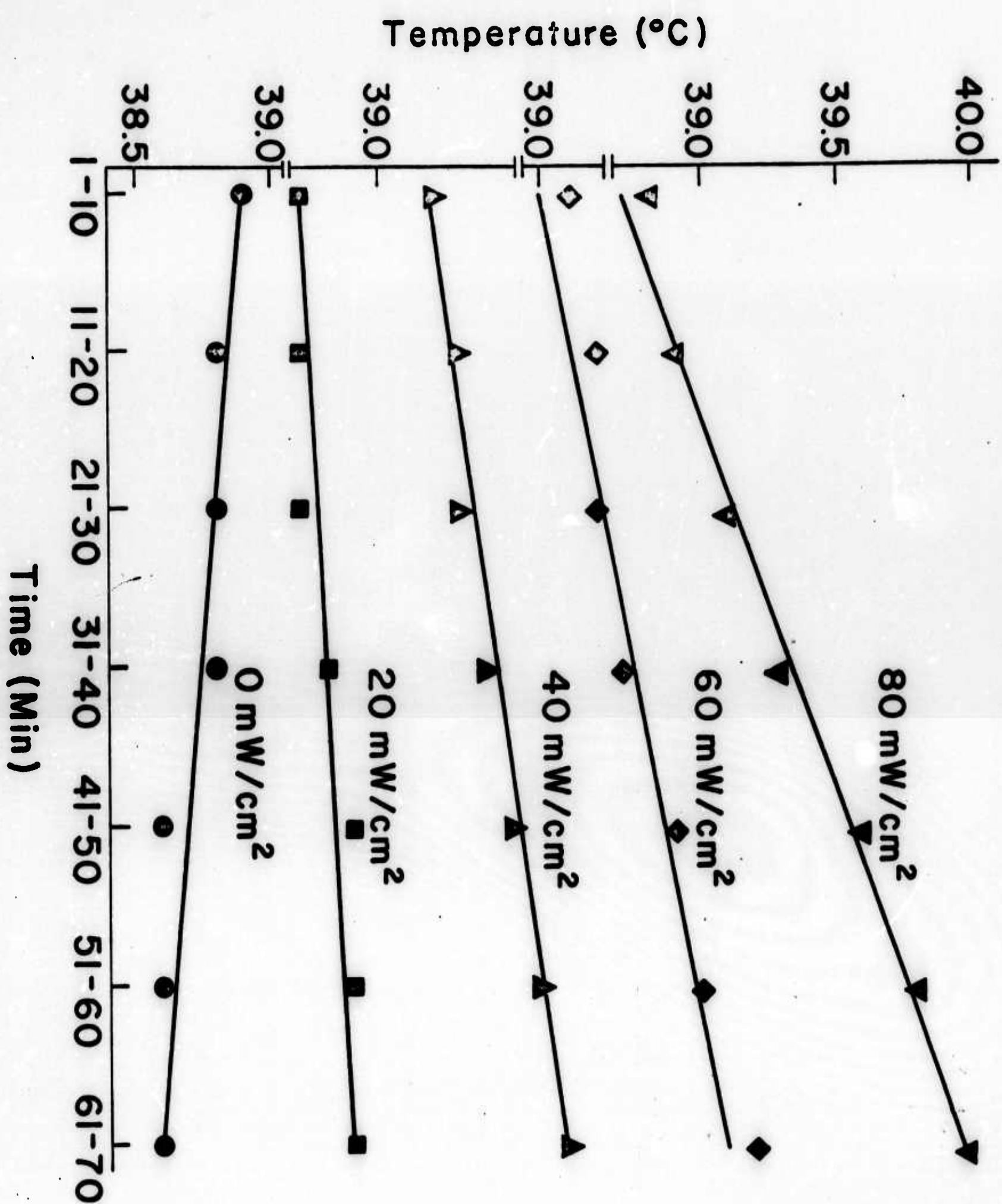


Fig. 3 Effect on subcutaneous temperature of CW microwave irradiation of the head

Table 1
CW Microwave Irradiation of the Head

Power density (mW/sq cm)	Change per minute of irradiation		
	Heart rate (beats/min)	Respiration* (breaths/min)	Temperature (°C)
0	-.17	-2.66	-.005
20	.00	.61	.004
40	.06	4.13	.008
60	.13	6.64	.011
80	.32	9.39	.021

*During the first ten minutes of irradiation

Table 2
CW Microwave Irradiation of the Whole Back

Power density (mW/sq cm)	Change per minute of irradiation		
	Heart Rate (beats/min)	Respiration (breaths/min)	Temperature (°C)
0	-.11	-.69	.002
10	.02	.30	.011
20	.07	2.46	.019

Table 3
Infrared Irradiation of the Whole Back

Power density (mW/sq cm)	Change per minute of irradiation		
	Heart Rate (beats/min)	Respiration (breaths/min)	Temperature* (°C)
10	-.10	2.05	.093
20	.00	2.00	.157

*During the first ten minutes of irradiation

Table 4
CW versus Pulsed Microwave Irradiation at 20 mW/sq cm

Rabbit	Change per minute of irradiation					
	Heart Rate (beats/min)		Respiration (breaths/min)		Temperature (°C)	
	CW	Pulsed	CW	Pulsed	CW	Pulsed
1	-.54	.02	4.60	5.95	.066	.069
2	.01	-.36	-.88	5.60	.055	.064
3	.05	-.11	4.58	4.39	.057	.076
4	.75	.29	3.08	3.18	.067	.068

Apparatus

The apparatus was the same as in Experiment I, except that the animal's back was not shielded from radiation, so that the head and back both were irradiated.

Procedure

The procedure, too, was the same as before, except that the animals were exposed twice to 0, 10, and 20 mW/sq cm, and records were taken every five minutes instead of every minute.

Results

The increases in heart rate, respiration rate, and temperature produced by whole-back irradiation were much larger than those produced by irradiation of the head alone. Figure 4 shows that the heart rate decreased at 0 mW/sq cm, increased more steeply at 20 mW/sq cm. As before, the plots are displaced vertically for legibility. Respiration rate decreased at 0 mW/sq cm, increased at 10 mW/sq cm, and increased markedly at 20 mW/sq cm, as shown in Fig. 5. Temperature, in Fig. 6, showed a definite increase at 10 mW/sq cm and an even larger increase at 20 mW/sq cm.

The rates of change per minute of irradiation are summarized in Table 2. Comparison with Table 1 shows that the increases in heart and respiration rates produced by whole-back irradiation at 10 and 20 mW/sq cm were as large as the changes produced by twice as much power applied to the head alone. The temperature increase was about five times as large as that produced by irradiation of the head alone. The increase in temperature was especially large, because with whole-back irradiation the thermistor was located in an irradiated area.

It is important to note that 10 mW/sq cm, a level considered the safety threshold for humans, produced definite physiological changes in the rabbit.

Experiment III

Infrared Irradiation of the Whole Dorsal Surface

Subjects

Two male albino rabbits weighing 3.5 kg.

Apparatus

The apparatus was the same as in Experiment II, except that the microwave source was replaced by an ordinary bowl heater, directed downward and suspended approximately 3 feet above the animal. Thermal power density was monitored with an Eppley thermopile. The temperature of the heater wires, measured with an iron-constantin thermocouple junction, was 800° F at 10 mW/sq cm and 1000° F at 20 mW/sq cm.

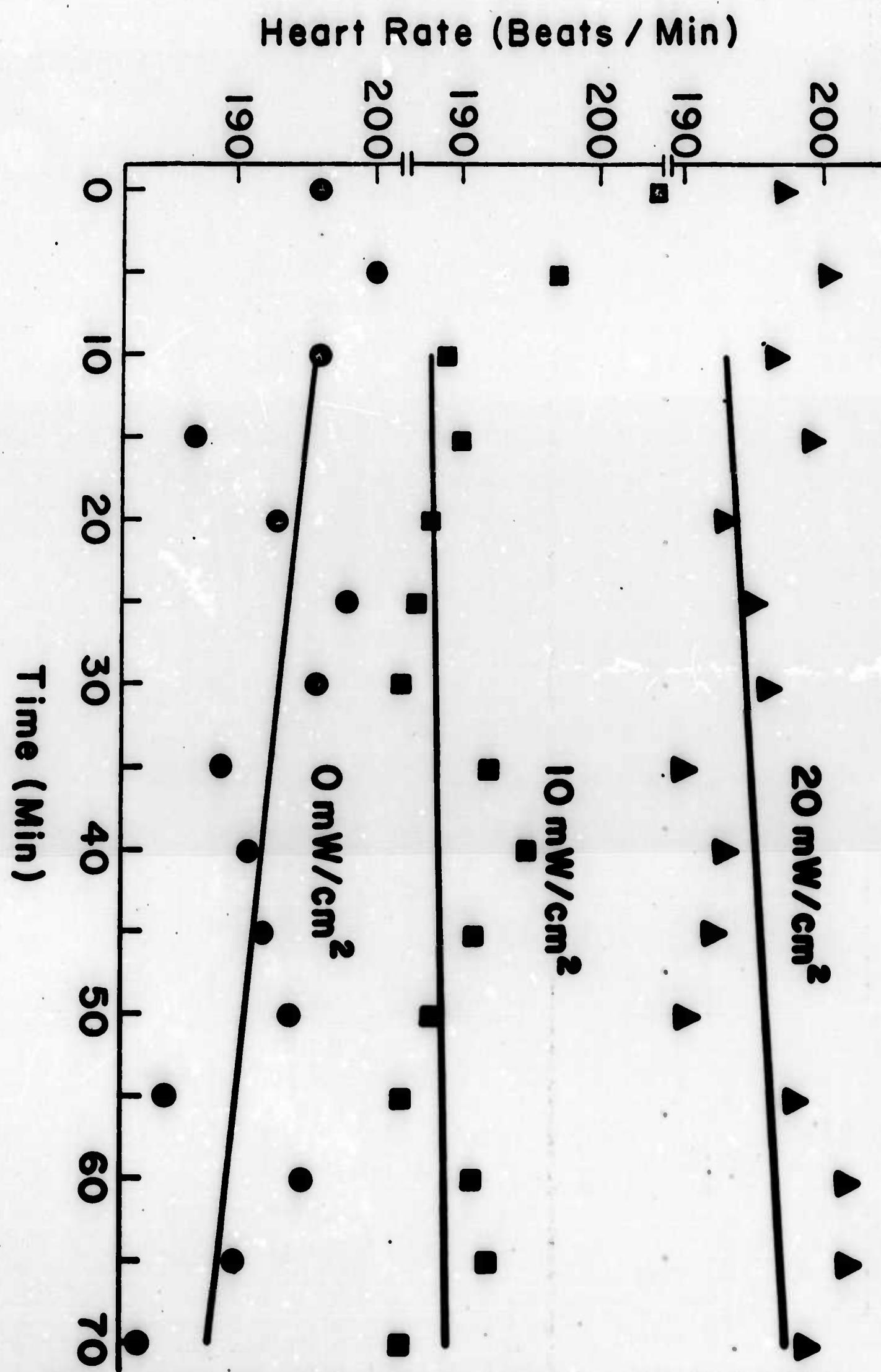


Fig. 4 Effect on heart rate of CW microwave irradiation of the head and back

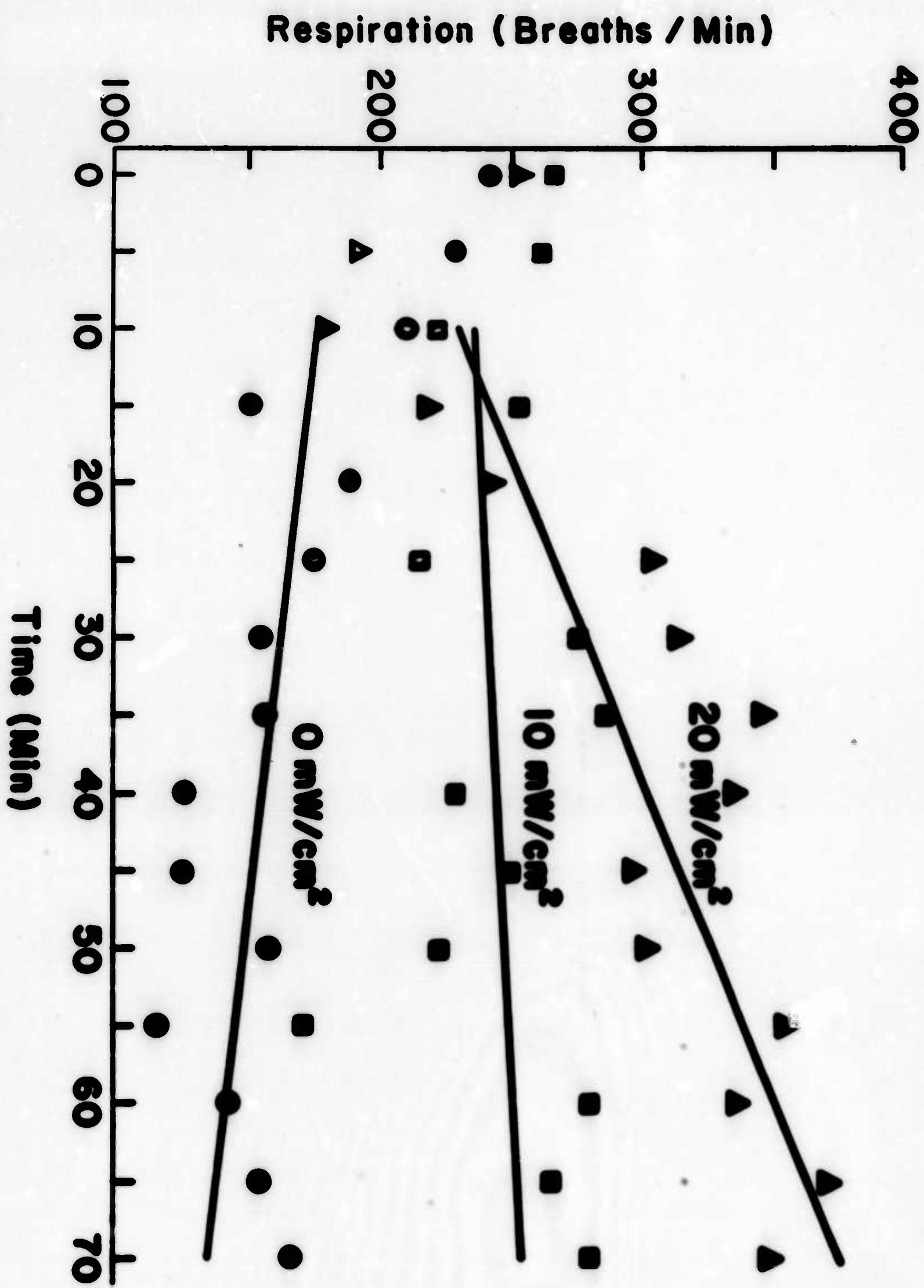


Fig. 3 Effect on respiration rate of CW microwave irradiation of the head and back

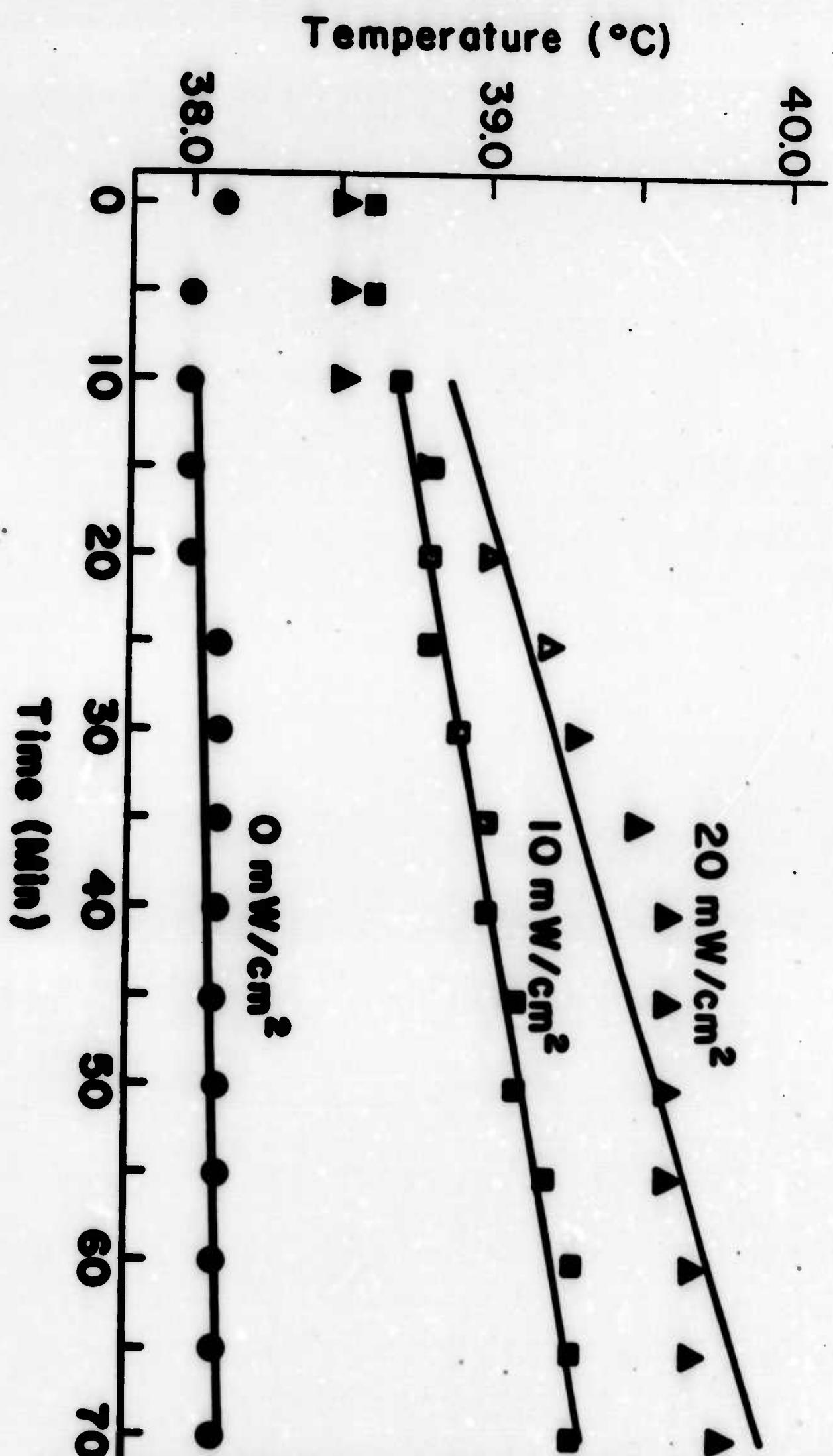


Fig. Effect on subcutaneous temperature of CW microwave irradiation of the head and back

Procedure

The procedure was the same as in Experiment II, except that the power levels were 10 and 20 mW/sq cm of infrared radiation. Data for 0 mW/sq cm were obtained from the same two animals during Experiment II.

Results

The effects of infrared radiation on heart rate (Fig. 7) and respiration rate (Fig. 8) were about the same as the effects of the same power densities of microwaves. The increase in subcutaneous temperature produced by infrared (Fig. 9) was much larger than that produced by microwaves. Table 3, which summarizes the changes per minute of infrared irradiation, shows that the temperature increase was about eight times as great as that produced by microwaves in Experiment II.

The increases in heart and respiration rates obtained in this experiment confirm the hypothesis that the corresponding microwave effects are also thermal in origin. The greater increase in subcutaneous temperature with infrared is consistent with the well-known fact that infrared penetrates tissue less deeply than microwaves.

Experiment IV.

Comparison of CW and Pulsed Microwaves

Subjects

The apparatus was the same as in Experiment II, except that the radiation was 2.8 GHz CW and pulsed with 1.3 μ sec pulse width at 1000 pps.

Procedure

The procedure was the same as in Experiment II, except that records were taken every two minutes for 20 min of whole back irradiation at 20 mW/sq cm. Each animal was exposed four times to pulsed and four times to CW in counterbalanced order.

Results

There was no significant difference between the effects of pulsed and CW microwaves on heart rate, respiration rate, or temperature. Figure 10 shows that there was very little difference in the rates of change in these indicators for pulsed versus CW during the period of irradiation from 10 to 30 min. The rates of change for the individual animals are summarized in Table #4. Difference t tests performed on the data in this table showed that none of the differences between the pulsed and CW conditions even approached significance at the .05 level.

If the heart and respiration rate effects, and of course the temperature effects, of microwave irradiation are thermal in nature, then pulsed and CW microwaves of the same frequency and average power should produce the

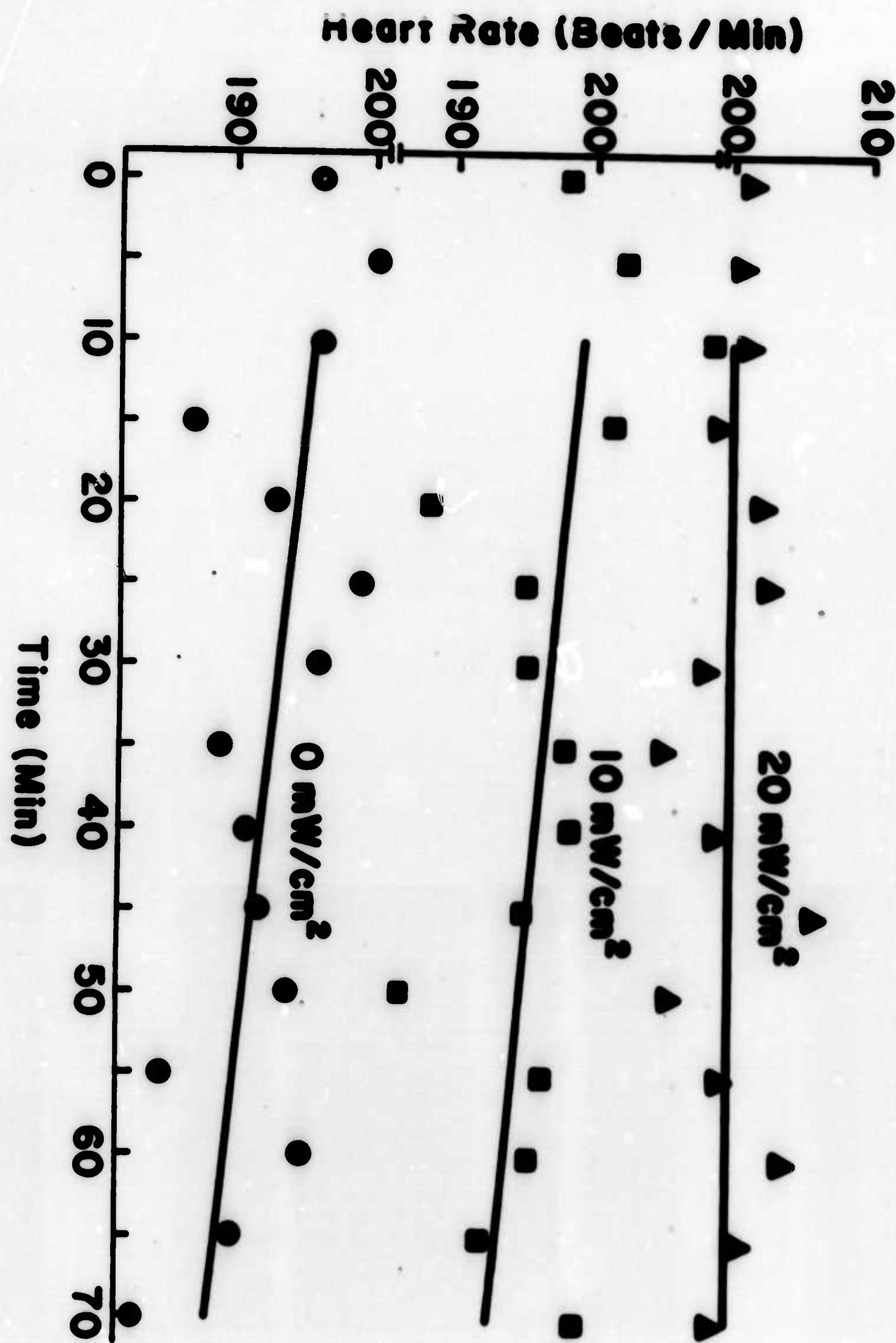


Fig 7 Effect on heart rate of infrared irradiation of the head and back

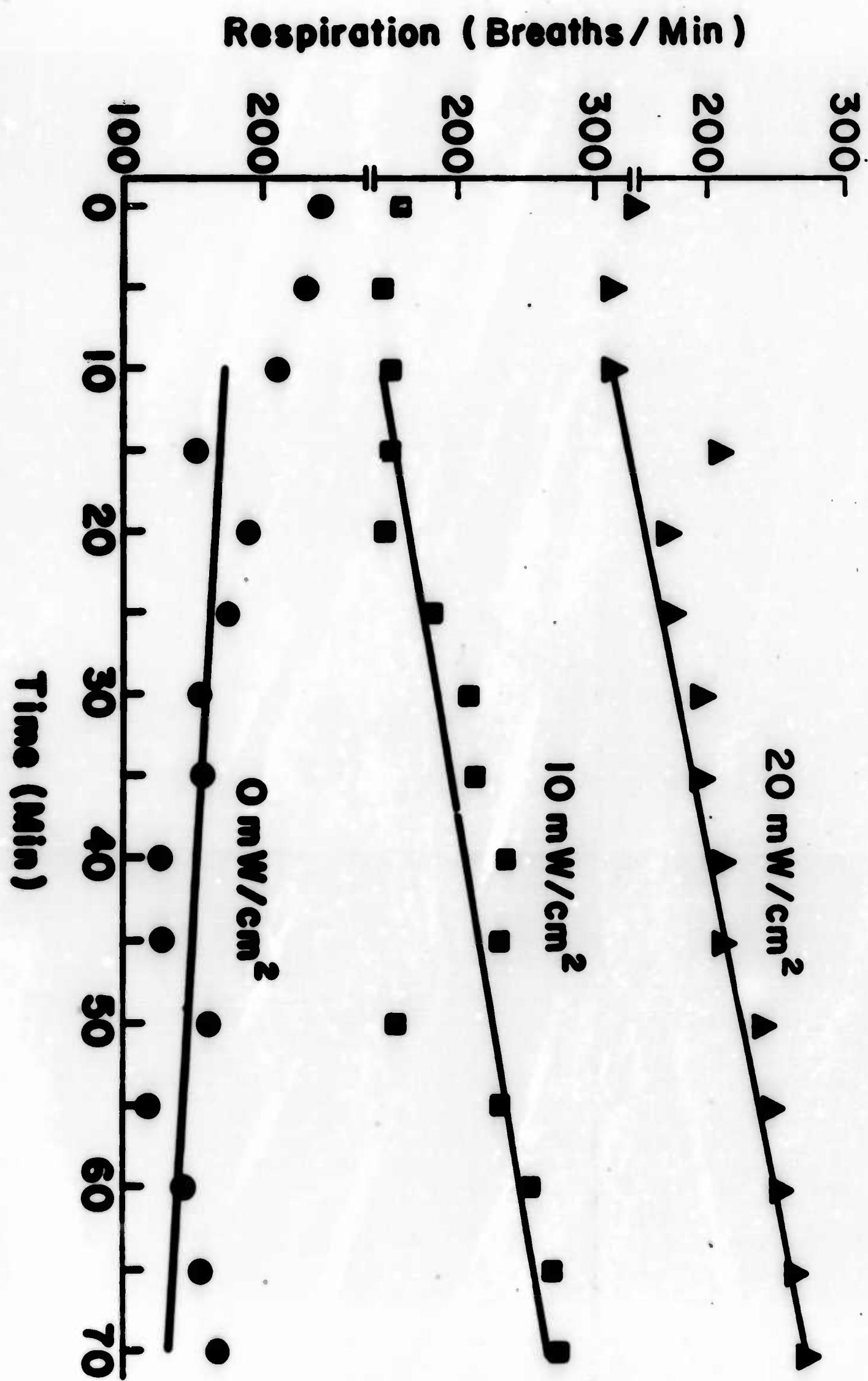


Fig 2 Effect on respiration rate of infrared irradiation of the head and back

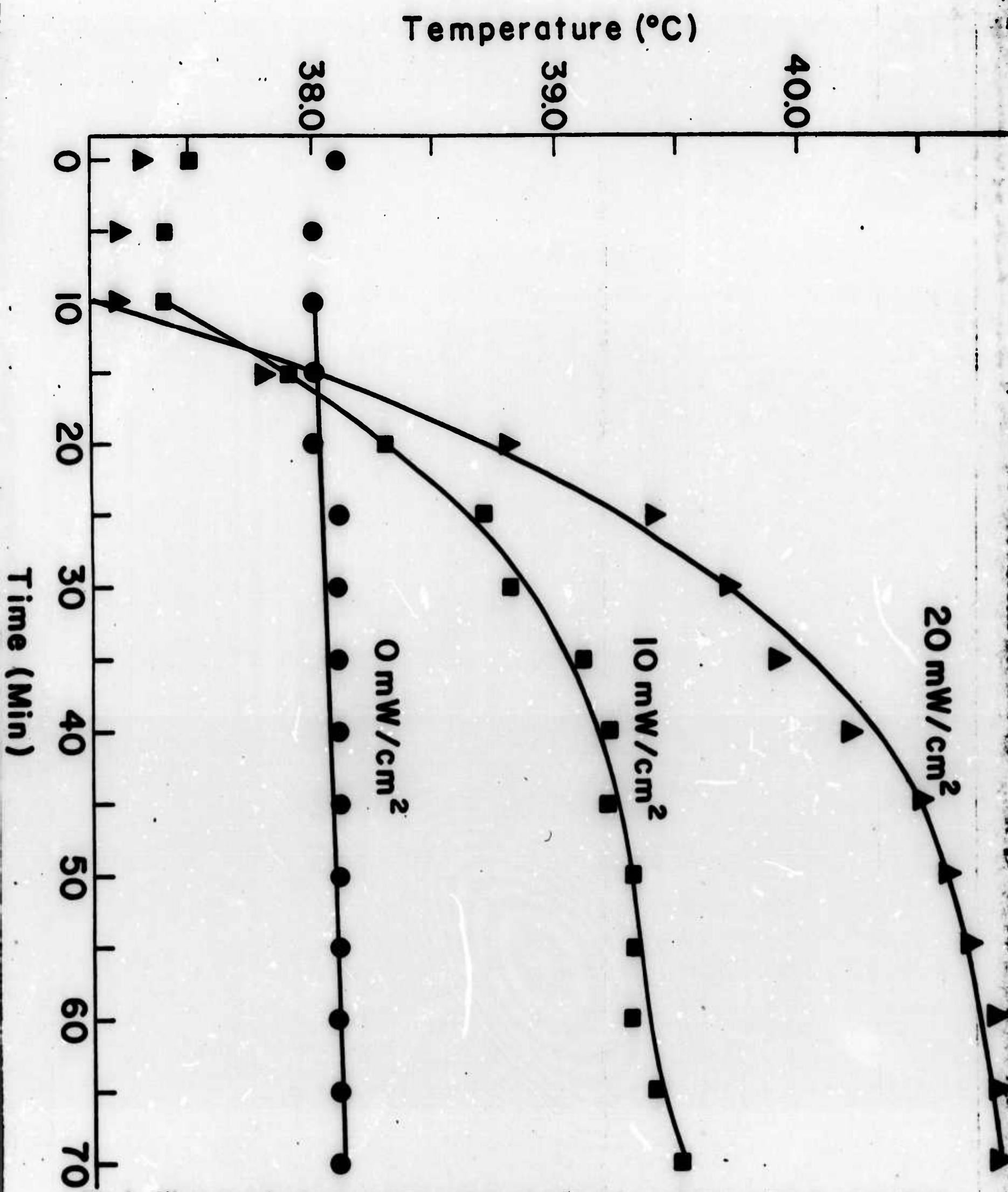


Fig 9 Effect on subcutaneous temperature of infrared irradiation of the head and back

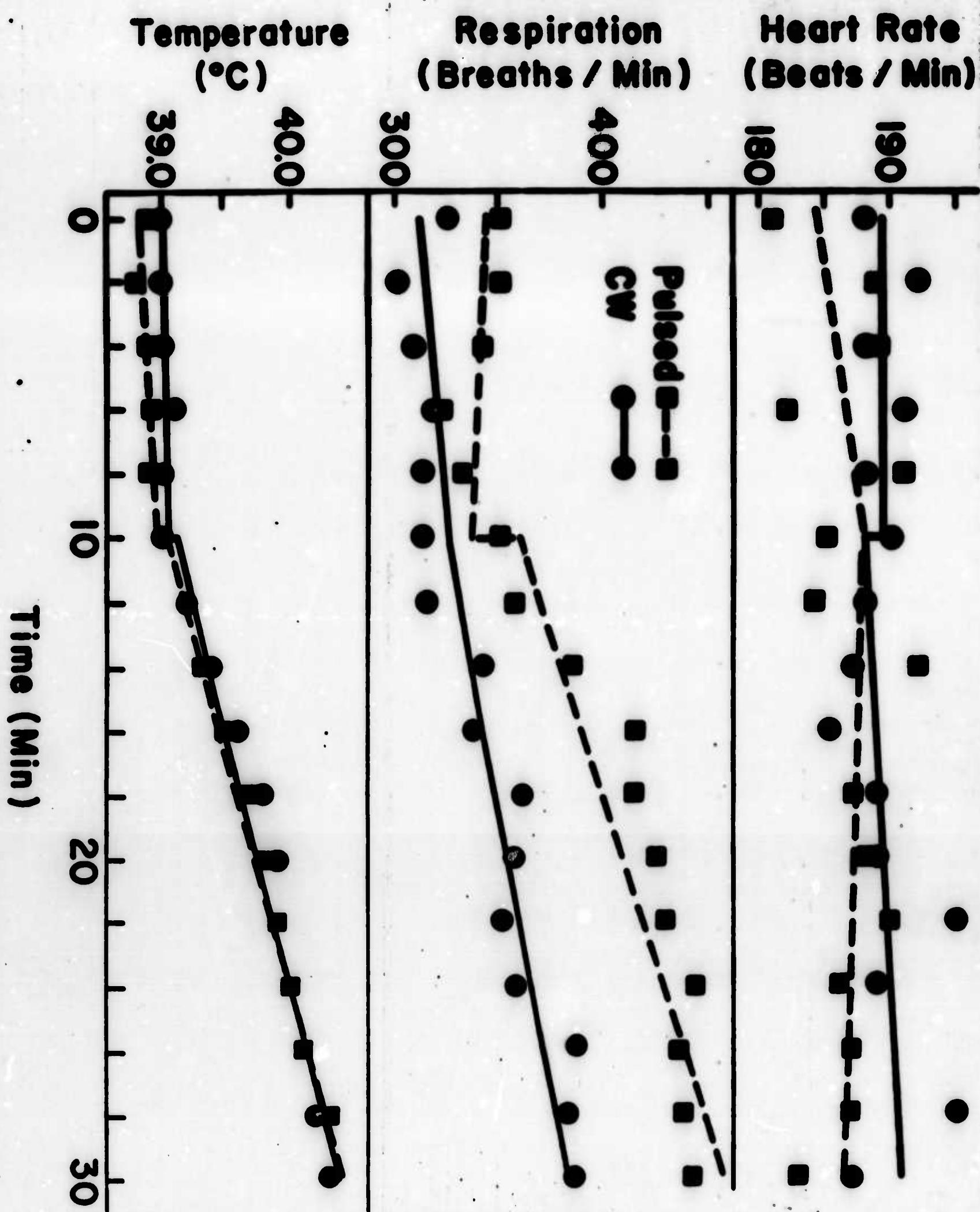


Fig 10 Comparison of the effects of pulsed and CW microwaves on heart rate, respiration rate and subcutaneous temperature

same effects. The results of this experiment confirm the thermal hypothesis for the conditions tested.

THE HUMAN MODEL

The objective of this portion of the research was to study the delayed effect of chronic microwave exposure on primates under conditions simulating human exposure. The primary objective was to search for cataractogenic effects and the species selected, *Macaque cynamologous*, has an eye comparable to humans. Secondary objectives were to look for any other findings which could be attributable to microwaves.

The simulated human exposure experiences were selected to represent four different conditions; namely, Group I typified a control, Group II the inadvertant exposure, Group III the intermittent exposure and Group IV the continuous daily exposure. During the period of developing the exposure protocol and of designing the apparatus, certain factors of human exposure which are ordinarily absent under experimentally controlled conditions could be examined. For example, the vast majority of human exposure to radio-frequency fields encountered in naval operations occurs under conditions where the man is supported on a metal platform. Frequently, he is also either surrounded by metal objects of varied configurations or separated from the irradiating source by metal grids or chain-link fencing or both, all of which produce complicated field perturbations. Further, he is frequently working with metal objects and tools which could induce spurious electric currents in his body.

Obviously, although it would be desirable to investigate each of these components in depth because they represent the actual conditions of human exposure, nevertheless, at this stage of experimentation, it was only possible to take a cursory look at such factors. This opportunity was afforded while developing the apparatus and procedure when first metal cages and then metal neck leashes were employed.

Apparatus

The exposure apparatus was an AN/SPS-10 radar set which operates in the frequency band of 5450 to 5825 MHz at a pulse rate of 625 to 650 per sec with a 1.3 μ sec pulse width. This was installed at Laulaunui Island in the West Anch of Pearl Harbor, the site of our primate colony. The area into which the free-field was irradiated had an irregular topography which ensured that, should a spurious field perturbation be created at one point, it would be improbable for the same conditions to exist at any other point along the same power-density isobar. Therefore, at each isobar, two different animal placement sites were selected.

Analysis of the irradiation field ray-tracings as corroborated by subsequent radiometry measurements indicated that it would be necessary to work relatively close to the antenna in order to obtain useful power densities,

e.g., in the vicinity of 10 mW/sq cm. Thus, at close distances to the reflector, of the order of its wide dimension, the beam coming from the antenna is practically cylindrical with a vertically oriented electric field. Here, the relative density of the emerging beam is determined primarily by the far-field radiation pattern of the feeder horn with greatest density in the center and decreasing symmetrically on both sides. In small regions where the field doesn't vary much, e.g., the site of fixation for a monkey, we have, very nearly, a field consisting of uniform vertical polarization of the electric field, almost no variation in phase and almost no variation in amplitude, thus, approximating a plane wave. Under these circumstances, "power density" as measured by some form of densiometer would be meaningful because it simulates a far-field condition.

To ensure that the incident radiation resembled a plane wave, that there were no significant ground reflections and that no significant field perturbations were present, the calculated power densities were checked by two different densiometry methods, one dependent on an antenna technique which would be incident plane sensitive and the other dependent on absorbed energy which would be omni-directional. All were found to be in general agreement.

For fixing animals to a given incident power density, initially an attempt was made to fabricate a lattice-type jungle gym out of plastic pipe to hold the animals to given positions. However, because of the need to provide care, such as water, food and cleaning for the animals during irradiation, it was found to be impractical to utilize such a rack because the attendant personnel would not be able to gain access to the individual animals in order to take care of their needs. Next, an attempt was made to utilize cages.

Various cages were studied and two types were tested. One was a heavy, molded polyethylene cage which, although low-loss, was rejected because of poor design for air circulation, a pre-requisite to minimize thermal stress, and for maintenance of a satisfactory hygienic state. The other was a metal cage designed to hold primates. After re-analyzing the field configuration being generated from the SPS-10 antenna, calculations were made of transmission through the cage grating, given the wire diameters and spacings, which were found to be close to 100% in the normal position of the cage with respect to the incident electric field and 70% in the worst possible position configuration. The calculations were tested experimentally and found to be accurate. In view of the fact that many naval exposure situations involve men being exposed through similar gratings while contained in metal surroundings, it was decided to begin preliminary exposures using the metal cages and to observe the effects of this condition. Meanwhile, further work was done to develop individual perch platforms in order to improve the experimental design by minimizing field perturbations.

The perch platforms were made of plastic and secured to a small length of plastic tubing directed downward from its base so that the plastic tube could be slipped over a metal rod driven into the ground. The various pieces were fastened together by nut-and-bolt construction. When this was completed, use of the cages was discontinued and, instead, each monkey was leashed to his own platform by a short chain attached to his neck.

Procedure

The experiments on lower-form animals indicated that the initial exploratory free-field, whole-body irradiations of primates should be conducted at a power-density of 20 mW/sq cm. At this intensity, it was predicted that a thermal response would be obtained with prolonged exposure. Therefore, pilot experiments were conducted by exposing monkeys for periods of hours to this power density. In order to accomplish this, it was necessary to sedate and restrain the subjects. The first animal, so tested, died of thermal stress several hours after an exposure duration of 165 minutes. Other animals survived exposure durations of 112, 110, 223, 110, 112, 335, 114 and 114 min at the same field position. In order to ensure that there was no spurious phenomenon associated with the specific exposure placement, a second position was selected, also at an incident power-density of 20 mW/sq cm, and additional exposures were made. One monkey died of thermal stress immediately following 180 min of exposure, while others survived exposure durations of 120, 177, 187, and 187 min each.

The monkey deaths appeared to be the consequence of heat exhaustion, therefore, it was necessary to eliminate or minimize all factors that could contribute to thermal stress. To eliminate the direct action of sunlight, a roof was constructed over the irradiation site. To eliminate the effect of drugs and immobility, the monkeys were placed in individual cages. Water and food were provided so that each animal could replace fluid, electrolyte and metabolite loss ad lib. Further, the animals could move about to ensure randomization and thereby minimize the potential for injury from hot-spots. Under these conditions, several exposures were made with animals caged individually and no untoward effects were noted. Group II, consisting of eight animals each of which received a total of eight hours exposure, were irradiated in this fashion so that a pair of animals were exposed to field intensities of either 1, 5, 10 or 20 mW/sq cm, the isobars selected for the ongoing exposures. Group II represented the inadvertant exposure.

As it appeared that the animals would tolerate exposure under these conditions, irradiation of Group III, receiving a six hour exposure for one day each week, and Group IV, receiving a six hour daily exposure, was instituted.

Observations over a duration of several months failed to reveal any

untoward effects from the irradiation. However, other factors requiring correction became evident. The cages were relatively large and crowded together to such an extent that the animal in some cages could reach through to an adjacent cage. This resulted in social interactions such as playing and fighting which reduced both centralization in the field and randomization of the exposure. Also, as the cages were suspended and not permanently mounted into fixed positions, some of the cages could be swung about, further reducing centralization and accentuating field perturbations. Satisfied that irradiation through a wire barrier while supported on a metal platform had no ill effect on the monkeys, the next stage in developing the exposure protocol was entered by leashing each animal to a small, individual perch platform.

As the animals were relatively wild, it was necessary to ensure that none would escape from its perch. As they were able to chew through plastic or leather, it was necessary to use metal chains to leash them in position. Keeping the leash relatively short ensured that each monkey would remain on his perch and prevented interaction between adjacent monkeys. Within the first two months of initiating the perch exposures, five of the 16 monkeys being so exposed died; one after having received daily exposure at 20 mW/sq cm for a cumulative 539.5 hr, another after weekly exposure at 1 mW/sq cm for 122.5 hr, another after weekly exposure at 20 mW/sq cm for 114 hr, another after daily exposure at 10 mW/sq cm for 570 hr and the last after daily exposure at 10 mW/sq cm for 45.7 hr. Most of the deaths appeared to have resulted from strangulation. Each of the monkeys that died was replaced.

During the following three month period of irradiation, no further deaths occurred. Concurrently, procedures were developed to ensure that each monkey received adequate support regarding food, water and general care during irradiation and it was noted that with the partial domestication of the animals, which resulted from their restricted motion and dependence on handlers, their dispositions became more gentle and their activity lessened. At this time, it appeared as if all of the major problems regarding survivability of the monkeys had been solved. Therefore, preparations were begun to institute the definitive program for chronic exposure. Eighteen new monkeys were selected and examined in order to provide eight animals each for a new Group III and a new Group IV with two spare animals for contingency purposes.

Prior to commencing the definitive chronic exposures, modifications were required in site preparation, apparatus and animal handling. The irradiation site required a concrete deck with multiple receptacles for eye-bolt attachments so that plastic pipe connections could be rigidly secured to this flooring. This was to be accomplished by embedding chain-link fencing throughout the concrete deck with a complete row of links just protruding through the

surface approximately every running linear foot, thus providing a vast network of floor connection points. Each small, individual perch platform was to have a hole drilled in its center for passage of the leash so that the leash could be fastened below the perch platform out of reach of the monkey. Also, each perch platform was to be set atop a tripod, fabricated of rigid plastic pipe, so that the base of each leg could be bolted to a suitable connection in the floor. The perch platform and tripod assembly were to be fabricated completely of plastic material with connections and joints secured by plastic fittings and cementing substances. Animals were to be domesticated and trained so that each monkey would be conditioned to wear a neck band and leash fabricated of plastic or leather material without attempting to work free and to remain on its perch without attempting to escape. Compliance with all of these easily attainable objectives would complete the development of the exposure methodology and protocol. However, the research effort was terminated before this stage of the investigation could be implemented.

Results

1. A protocol was developed whereby simultaneously a large number of primates can be irradiated chronically with radiofrequency radiation in a biological assay method simulating types of exposure humans experience when working in the vicinity of operational equipment. It provides, for the first time, a method to test the adequacy of current health-safety practices.
2. A laboratory study, conducted under fully controlled exposure conditions, indicated that significant thermal effects are produced in the experimental animal by microwave irradiation at incident power densities of 10 mW/sq cm, that these effects are markedly increased at 20 mW/sq cm and that the threshold for prolonged, repeated exposure should be searched for at intensities of irradiation much less than 10 mW/sq cm. Based on this data, supported by the finding that some stressed primates could not survive prolonged exposure at 20 mW/sq cm, the four isobars of incident irradiation for the chronic monkey exposure experiments were set at 20, 10, 5 and 1 mW/sq cm.
3. Aside from the monkey deaths, the only other significant finding was that one monkey developed a peculiar behavior pattern, intermittently and repeatedly holding the left side of her face and head as if she had a headache, after being exposed to 5 mW/sq cm for six hr durations at weekly intervals for a total of 122 hrs. The irradiation was continued at the same rate of delivery until termination of the exposures at which time it totalled 256 hrs and the monkey's abnormal behavior continued.
4. The experimental exposures were terminated on February 16, 1971, and no evidence of microwave cataracts was noted in any monkey at that time. Needless to say, this search should be continued into the future because of the long latency anticipated at exposure levels under 100 mW/sq cm.

5. The cumulative exposure records for the surviving monkeys is as follows:

Group I-controls

Group II-exposed for eight hours in May 1970

<u>ID#</u>	<u>mW/sq cm</u>
10	20
5	20
46	10
29	10
27	5
56	5
6	1
2	1

Group III-exposed for a six hr period at weekly intervals

<u>ID#</u>	<u>mW/sq cm</u>	<u>Total hrs</u>
72	20	225
77	20	91
90	10	222
84	10	226
88	5	225
85	5	256
104	1	106
86	1	225

Group IV-exposed for a six hr period at daily intervals

<u>ID#</u>	<u>mW/sq cm</u>	<u>Total hrs</u>
100	20	1097
89	20	547
47B	10	417
81	10	1065
82	5	1092
80	5	1044
101	1	1092
79	1	1084

Conclusion

A pragmatic, bio-assay experimental method was developed whereby meaningful radio-frequency hazard data can be obtained. The technique can be applied to any type of pure or mixed radio-frequency field from the simplest to the most complex. The animal, itself, serves as the cumulative dosimeter for registering psycho-physical effects. By utilizing two primates for each intensity-

duration function tested, the probability of a spurious radiation field effect is rendered negligible. By selecting the animals as a pair, one male and the other female, the entire spectrum of potential sex-related delayed effects, including mating, fertility, gestation and progeny, may be investigated. In addition to the search for specific, radiation induced signature pathology such as thermal cataracts, other types of pathology and functional disorders including behavioral and psycho-physical abnormalities may also be investigated simultaneously. The concept of developing health-safety data by the technique pioneered in this program represents one of the most meaningful state-of-the-art advances for determining radio-frequency hazards developed during the past decade.

Recommendation

Although sponsorship was terminated prematurely, nevertheless, it is obvious that the animals exposed during the evolution of the protocol should be kept alive for long term observation not only because this is the only group of animals that has been exposed to radiation under conditions similar to which humans are exposed but also because their exposure histories are known better than in any single case of human exposure, including the many documented cases of injury.

More obvious is the need for continuing the study in order to irradiate the additional, new Group III and IV monkeys under conditions of minimal metal surround.

Most obvious, however, is the urgent need to expand the work-scope of this study so as to apply its principles to the many operational exposure situations of concern to the Navy. To accomplish this in a timely fashion requires maintaining intact the unique capability, developed in the course of this investigation, which is dependent upon access to both the Zaret Foundation's self-perpetuating primate colony and the variety of operational radio-frequency fields available to the Navy. Having been denied the support to continue the investigation, the Zaret Foundation elected to donate as a gift its primate colony to the Navy so that the Navy could continue this vitally important study uninterrupted on an in-house basis.